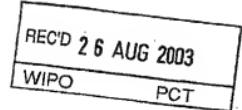




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מערכות הדמייה ושיטה להערכת מצב הגוף

Imaging system and method for body condition evaluation

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IMAGING SYSTEM AND METHOD FOR BODY CONDITION EVALUATION

FIELD OF THE INVENTION

The invention is generally in the field of monitoring techniques, and relates to a monitoring method and system for body condition evaluation, particularly useful for estimating the body condition score of dairy cows.

5 BACKGROUND OF THE INVENTION

Measuring a variety of attributes of animals, such as cows or beef cattle, is of high importance for farmers. Techniques aimed at determining animal traits, such as the identification of a specific animal, recognizing and determining the position of an animal or a specific part of it, or physical characteristics of an animal defining its 10 economic value, have been developed, and are disclosed, for example, in the following patents.

US Patent No. 5,412,420 discloses a technique for measuring three-dimensional (3D) phenotypic characteristics of dairy cows. A 3D image is created by projecting several laser light beams and measuring their reflections with a single laser 15 camera that scans a surface area of the animal and measures the distance at each point between the camera and the surface of the animal. By this, a total modeling of the animal's surface is provided. The camera generates a detailed map of the entire animal within the scanned space, assigning intensity and range values to each surface point that receives a laser signal. The obtained image is then analyzed by linear, 20 angular or volumetric means. There are currently 15 conformation traits that are measured for Holstein Cows. After each trait is measured by the system, it is then converted to a scale of 1 to 50. Known as the rating of each trait, this conversion to a scale of 1 to 50 compares each cow measured to those represented within the biological extremes of the breed.

US Patent No. 6,234,109 discloses an apparatus and method for recognizing and determining the position of a specific part of an animal, e.g., the teat of a dairy cow, to guide an animal-related device towards the determined position of said part. The apparatus comprises a source of structured light for illuminating a surface region 5 to enable identification of this specific part. The source of structured light is obtained by using a grid associated with a light-emitting element. The apparatus also comprises an image capture and processor means arranged to capture and process at least one image formed by said light, and control means to determine if the illuminated object includes said specific part by comparing the image of the 10 illuminated object to reference criteria defining different objects, and if so, to establish the position thereof of the illuminated object.

US Patents Nos. 5,483,441 and 5,576,949 disclose a system for animal evaluation through image acquisition. According to this technique, an animal is evaluated to determine characteristics or traits thereof. The animal is evaluated as it 15 moves through first and second scenes that correspond to different first and second fields of view along two essentially perpendicular lines of sight. Evaluation is carried out by comparing the so-obtained gray level to certain threshold values.

US Patent No. 5,398,290 discloses a system for measuring intramuscular fat in live cattle by an ultrasound device to produce ultrasound image of an interior 20 muscle portion. The image contains speckles caused by the scattering of ultrasound waves by the intramuscular fat. Image data representative of the speckles are analyzed in a computer in terms of pixel gray areas to produce a measure of intramuscular fat.

The monitoring of body condition score (BCS) of dairy cows is a very 25 important aid in defining their herd management. The BCS is known as a herd technique for determining the energy balance of dairy cows to define *inter alia* the amount of food needed for a particular group of dairy cows. According to this technique, an area on the cow's body in the vicinity of the tail head is inspected. This technique consists of the visual inspection of the vicinity of the tail head carried out 30 by a skilled person, who determines the dairy cow's condition and assigns to the

specific cow a corresponding mark from several accepted marks. The results of such a manual inspection strongly depend on the experience of the specialist carrying out the inspection.

SUMMARY OF THE INVENTION

5 There is accordingly a need in the art to facilitate the automatic monitoring of the body condition score (BCS) of dairy cows, by providing a novel imaging method and system capable of determining the BCS of a specific dairy cow.

10 The main idea of the present invention consists of imaging a region of interest on the rear part of a dairy cow to obtain a three-dimensional representation of the region of interest and by that determine the BCS scale of the images cow. The region of interest includes the rear part of the cow in the vicinity of its tail head. This can be implemented by determining, from the 3D representation of the region of interest, a predetermined measurable parameter indicative of the curvature of the region of interest. Then, previously prepared reference data representative of the BCS scales 15 and corresponding values of the predetermined measurable parameter can be used to analyze the determined value of this parameter for the specific imaged score and estimate the corresponding value of the BCS scale.

20 The term "*curvature*" signifies data indicative of a topographic map (surface relief) of the region of interest, and is actually representative of the surface defined 25 by the volume of the region of interest. Preferably, the curvature is determined with respect to a predefined plane (reference plane) tangential to the region of interest, preferably, to the rear part of the cow at the point of both pins bones and tail.

There is thus provided according to one aspect of the present invention, a method for determining the body condition score (BCS) of a dairy cow, the method 25 comprising:

- (i) imaging a region of interest including the rear part of the cow in the vicinity of its tail head, and generating data indicative thereof;
- (ii) processing the generated data and obtaining a three-dimensional representation of the region of interest;

(iii) processing said three-dimensional representation to determine the BCS of the dairy cow.

The imaging includes acquiring one or more image of the region of interest by illuminating the region of interest with structured light (i.e., a two-dimensional array 5 of spatially separated light components) and collecting light scattered from the illuminated regions. The image is then processed to calculate the predetermined measurable parameter indicative of the curvature of the region of interest, and utilize the reference data to determine a value of BCS corresponding to the calculated value 10 of the predetermined parameter. The image acquisition may be carried out by one or two pixel-array detectors. The reference data is previously prepared by applying measurements with both the conventional and inventive technique to dairy cows, and is representative of the body condition score scales (values) and corresponding values 15 of the predetermined measurable parameter.

The measurable parameter indicative of the curvature of the region of interest 20 may be at least one of the following: a distance (height) of the extreme point in the topographic map (determined as a distance between the reference plane and a point in the region of interest mostly distant from the reference plane); the area of a cross-section of the topographic map in a plane perpendicular to the reference plane (surface area defined by the illuminated surface regions in the plane perpendicular to 25 the reference plane) and including the extreme point in the map; and at least a part of the volume defined by at least a predetermined region of the topographic map (illuminated surface regions) with respect to the reference plane.

According to another aspect of the present invention, there is provided a method for determining the body condition score (BCS) of a dairy cow, the method 25 comprising:

- providing reference data representative of the BCS scales and corresponding values of a predetermined measurable parameter indicative of the curvature of a region of interest including the rear part of the cow in the vicinity of its tail head;

- imaging the region of interest by illuminating a two-dimensional array of spaced-apart illuminated regions within the region of interest, collecting light returned from the illuminated regions, and generating data indicative thereof;
- processing said generated data to obtain a three-dimensional representation of the region of interest and calculate a value of the predetermined measurable parameter from said three-dimensional representation; and
- utilizing said reference data to determine the BCS scale corresponding to the calculated value of said predetermined measurable parameter.

The processing of the data indicative of the acquired image includes

10 determining a shift of the location of each of the illuminated regions on the surface of the cow's body caused by the curvature of the surface. If a single image is acquired, such a shift is a distance between the actual location of the illuminated region on the curved surface and corresponding location along the trajectory of the corresponding light component (i.e., a theoretical location of the corresponding region on the

15 surface, if the surface were substantially flat). If two images are acquired with different angles of collection of light returned from the region of interest, the shift a distance between locations of the two illuminated regions of a matching pair of regions in the two images (Parallax). To this end, the processing preferably includes determining the central points of all the illuminated regions. The shift is indicative of

20 the height of the respective point in the map (3D representation), and is determined utilizing data indicative of the detectors' location with respect to each other and relative to the region of interest, or the single detector's location relative to the region of interest and to the trajectories of the incident light components.

According to yet another aspect of the present invention, there is provided a

25 system for determining the body condition score (BCS) of a dairy cow, the system comprising:

30 (a) an optical device including an illuminator operable to produce a two-dimensional array of spatially separated light components to thereby illuminate a two-dimensional array of regions within a region of interest on a body part of the dairy cow, and a light detection assembly operable for

acquiring at least one image of the illuminated body part by collecting light scattered therefrom and generating data indicative of the acquired image;

5 (b) a control unit connectable to the optical device, the control unit comprising a memory for storing reference data representative of the BCS scales and corresponding values of a predetermined measurable parameter that is indicative of the curvature of a region of interest including the rear part of a cow in the vicinity of its tail head; and a data processing and analyzing utility preprogrammed for processing the data indicative of the acquired image to calculate a value of the measurable parameter for the specific imaged cow, 10 and analyze the calculated value with respect to the reference data to thereby determine the BCS scale of the specific dairy cow.

The illuminator may have one of the following configuration: it may be composed of a single light emitting element and a mask formed with a two-dimensional array of spaced-apart light transmitting regions spaced by light blocking 15 regions; may be formed by a two-dimensional array of spaced-apart light emitting elements (lasers); may be a scanner, namely a light source (e.g. laser) that moves rapidly and scans the area; may be composed of one or more linear light sources or line scan; or may include a diffraction mask that creates a pattern.

BRIEF DESCRIPTION OF THE DRAWINGS

20 In order to understand the invention and to see how it may be carried out in practice, preferred embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic illustration of the main components of the imaging system according to the present invention;

25 Figs. 2A and 2B illustrate two different examples, respectively, of an illuminator suitable to be used in the system of Fig. 1;

Fig. 3 illustrates the region of interest on the body part of the dairy cow illuminated by the illuminator of either one of Figs. 2A and 2B;